LPP EUV Source Production for HVM

October 19, 2010

David C. Brandt*, Igor V. Fomenkov, Alex I. Ershov, William N. Partlo, David W. Myers, Daniel Brown, Richard L. Sandstrom, Bruno La Fontaine, Alexander N. Bykanov, Georgiy O. Vaschenko, Oleh V. Khodykin, Norbert R. Böwering, Palash Das, Vladimir Fleurov, Kevin Zhang, Shailendra N. Srivastava, Imtiaz Ahmad, Chirag Rajyaguru, Silvia De Dea, Richard R. Hou, Wayne J. Dunstan, Peter Baumgart, Toshi Isihara, Rod Simmons, Robert Jacques, Robert Bergstedt

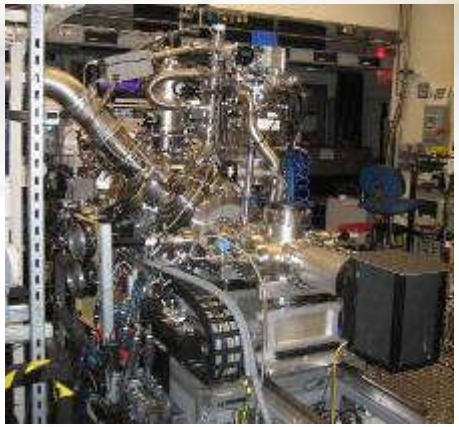
CYMER

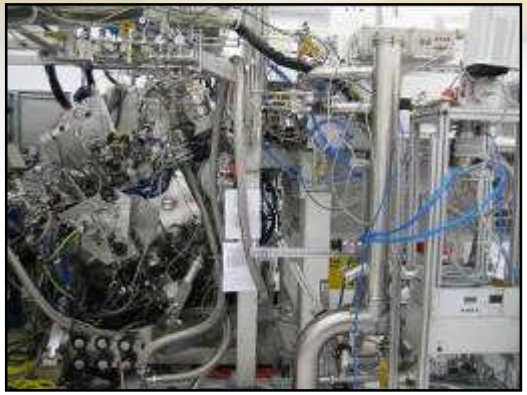
Leading the Light Generation.

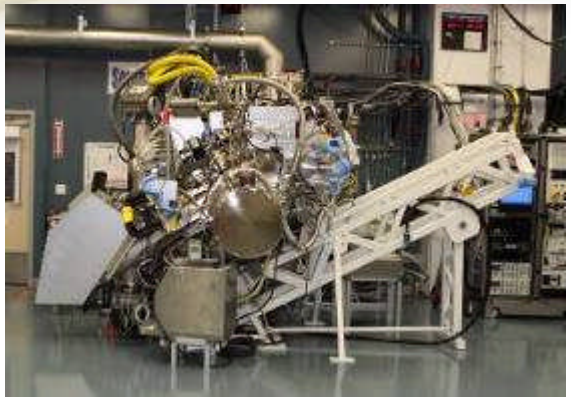
Summary - 2010 Progress Since SPIE in February

- HVM I Implementation
  - Four sources shipped
    - multiple qualification test runs completed with good results
    - multiple installations completed
  - Field support staff in place at ASML and at chipmaker sites
  - >70% source availability achieved at ASML
  - <27nm features exposed using a Cymer source at ASML
- HVM I Source Performance
  - Two internal HVM I sources are operational in San Diego for qualification and life testing
  - 100 hrs at 40% duty cycle qualification tests completed
  - 175W raw power feasibility demonstrated
- HVM II source development is in process

Cymer LPP EUV Sources in Use, and in Production







LT1

- Primary use is technology feasibility
- Technology developed on LT1 is transferred to products at a later date (after Engineering design)
- Being used for power scaling development

Prototype

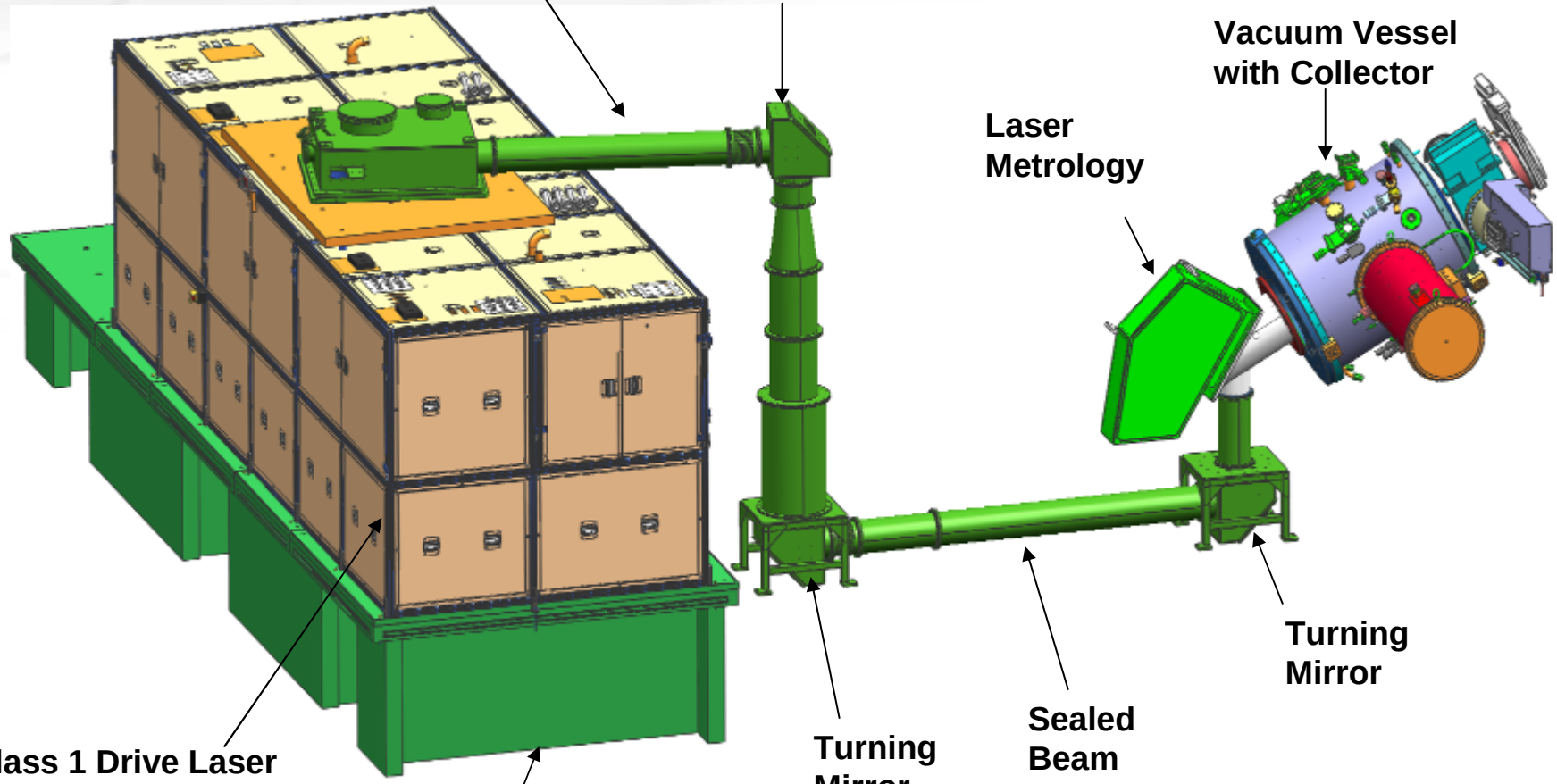
- Installed at ASML in 2009
- Provided good learning on controls and sensors, installation and support
- Now decommissioned

HVM I

- Six sources being built for shipment to customers
  - **Four sources shipped**
- Two internal HVM I sources for development at Cymer

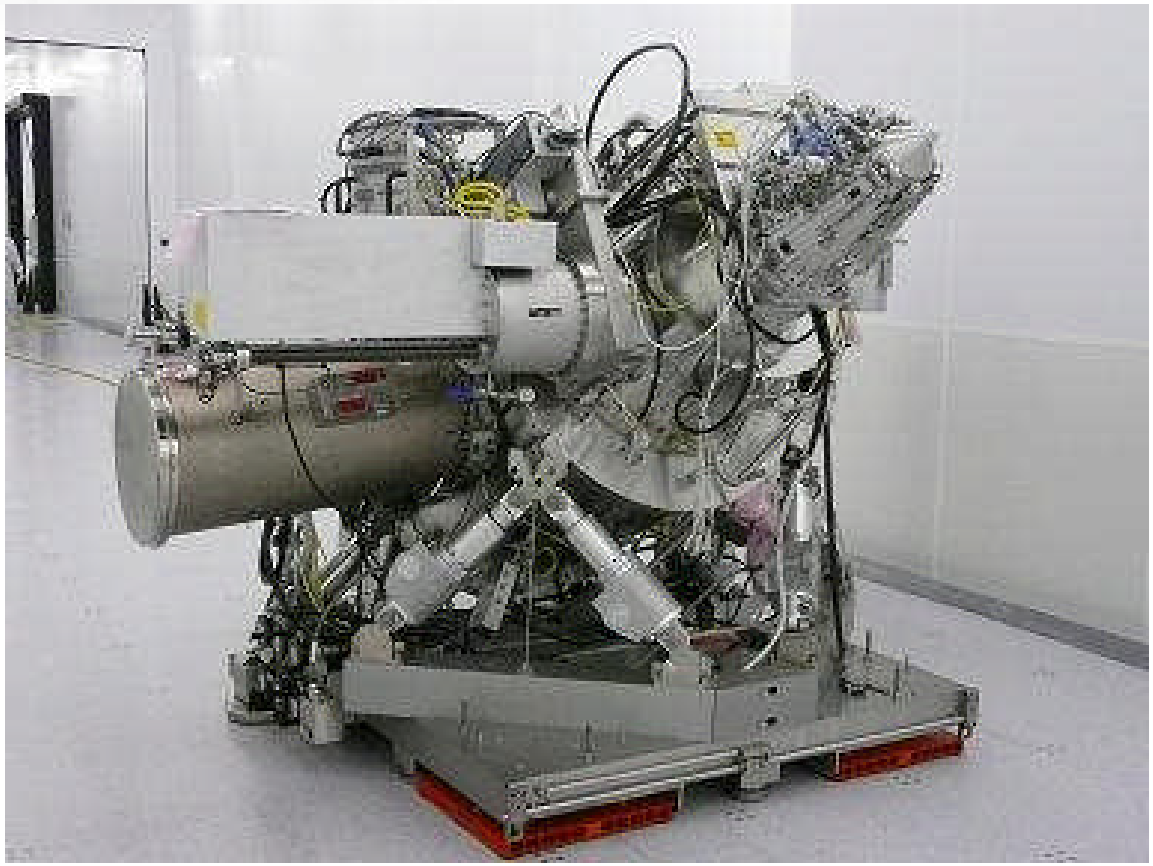
Laser Produced Plasma EUV Source Layout

Single Floor

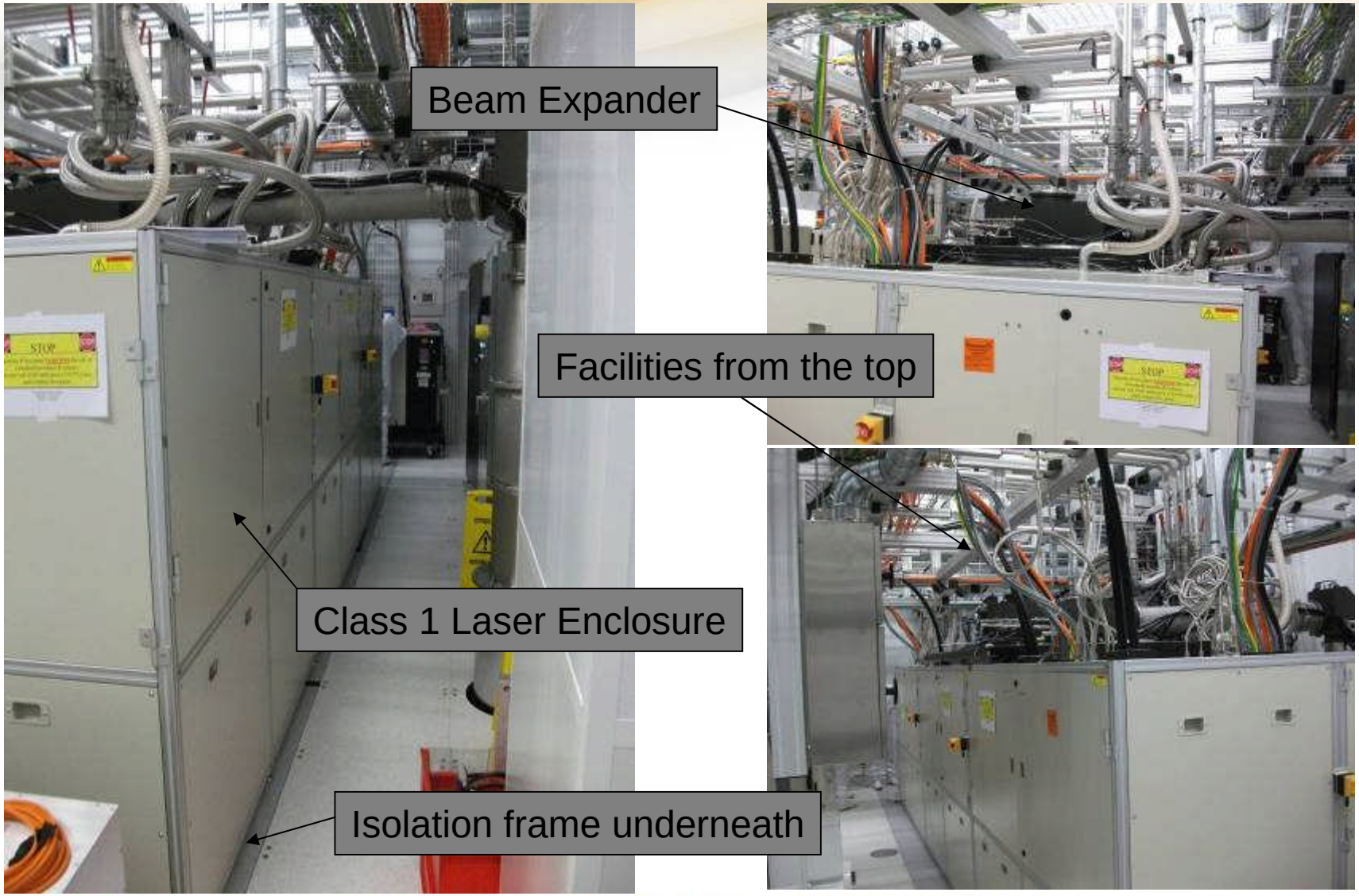


First Cymer EUV Source Delivered in April

1st HMV1 source being moved into the cleanroom at ASML



CO_2 Drive Laser Installation at ASML



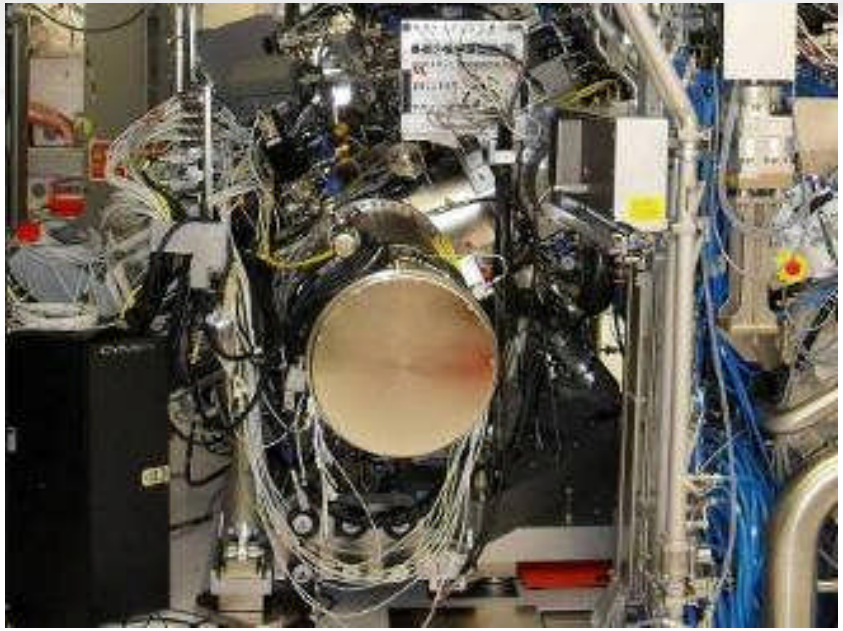
First Cymer Source is Installed on Proto 2 NXE-3100

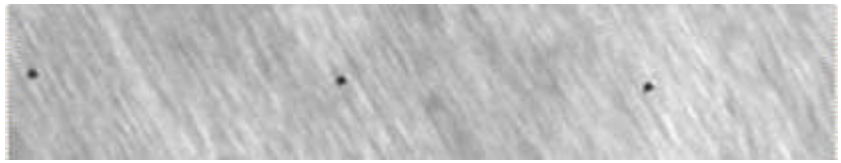
Operational Since July

- First HVM I source used for full field full wafer scans that meet the target resolution
- System is staffed and supported 7 days/wk x 16-24 hrs/day

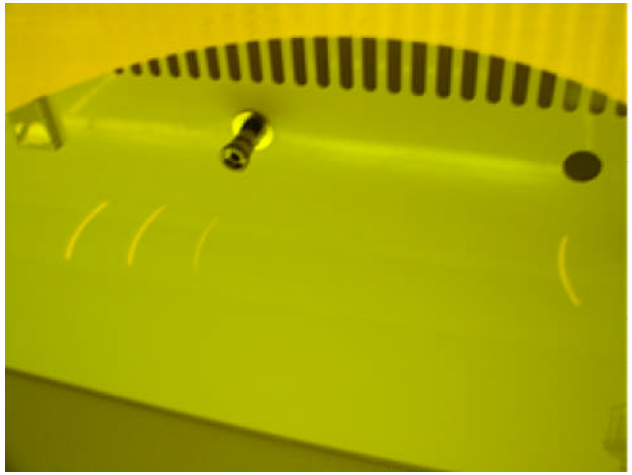
First Exposures with HVM I Source in July

First exposures with Cymer LPP Source





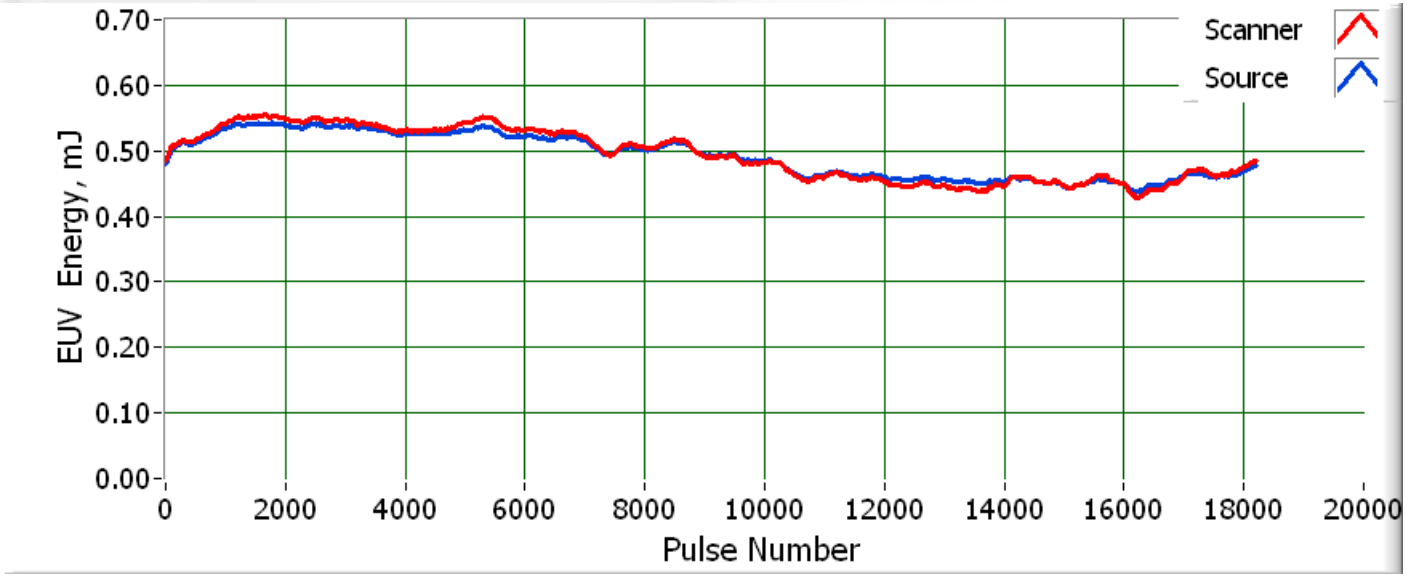
- **30μm diameter Sn droplets**



- **First static exposures in July showed the illuminated slit in photoresist**

Source Power Confirmed by Scanner Sensors

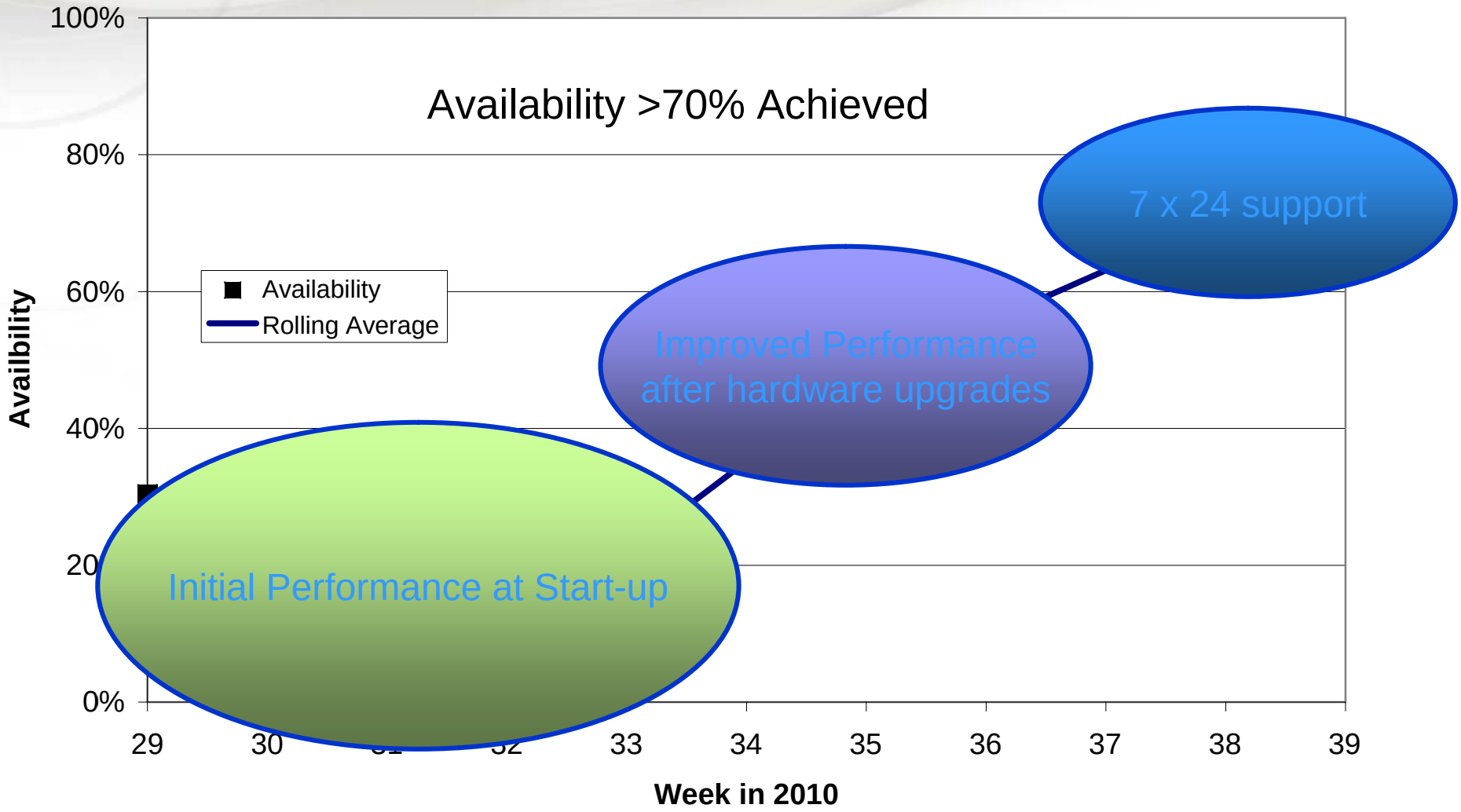
First independent power measurements agree well



- Independent IF Power Measurement by Scanner Energy Sensor
  - Measured by scanner energy sensor at the reticle (calculated to IF)
  - Measured by source energy sensor at plasma (calculated to IF)
- 0.5mJ per pulse at 40kHz = 20W

Cymer EUV Source #1 Uptime at ASML

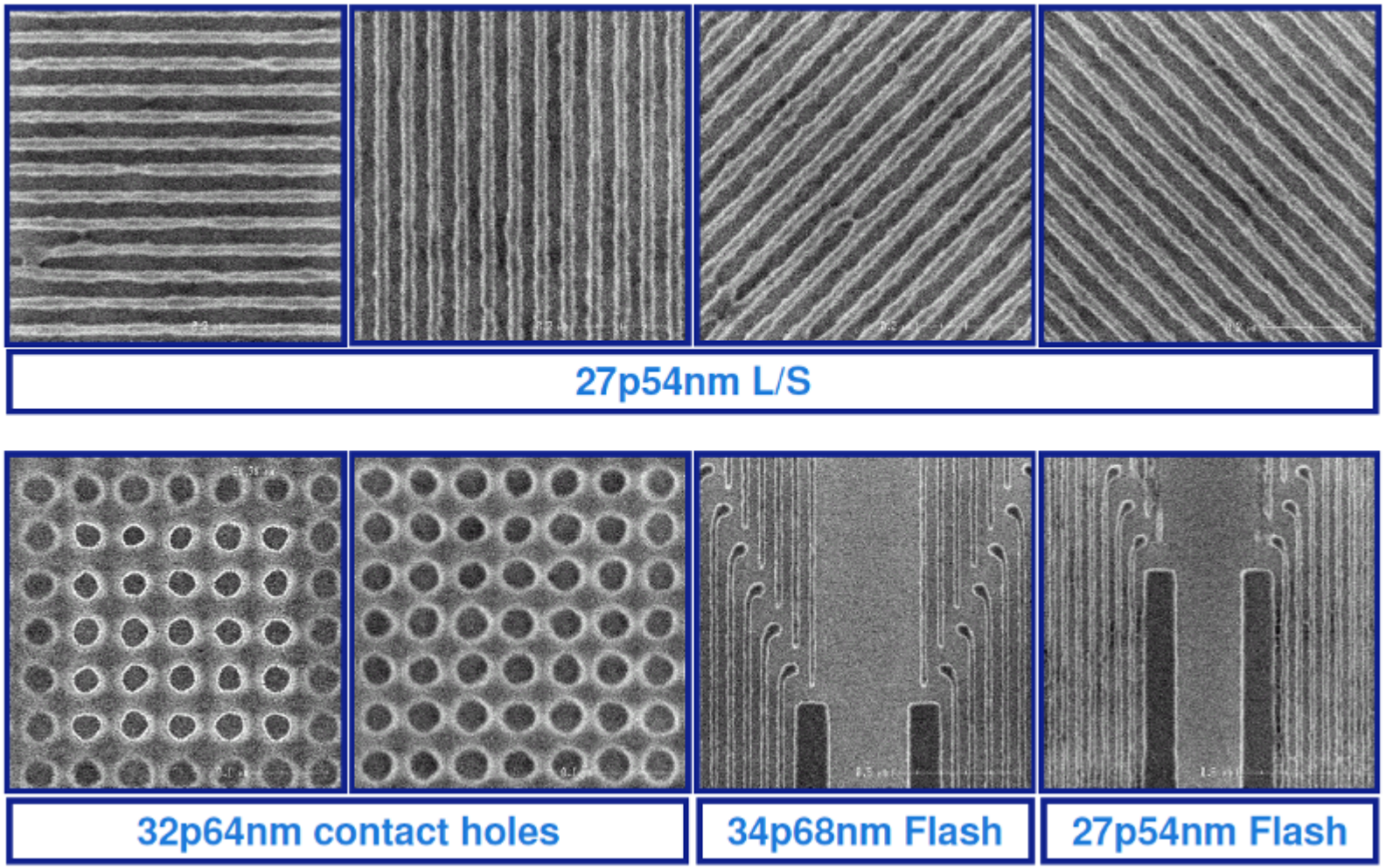
SEMI E10 Definition



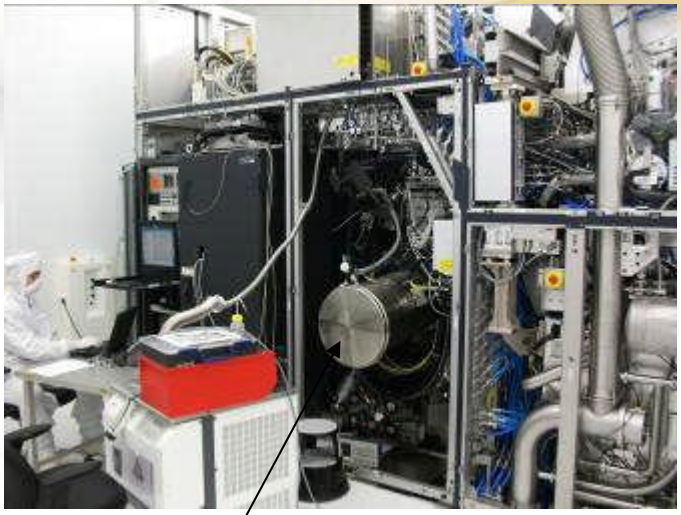
27nm Scanning Lithography using LPP Source

Enabling EUV lithography

- Printing on NXE:3100 Proto 2 using Cymer's HVM I source #1



Second HVM I Source Delivered in July



Source Vessel

Class 1Drive Laser

Master System Controller (MSC)

Third HVM I Source Delivered

- Drive laser is installed
- BTS is installed

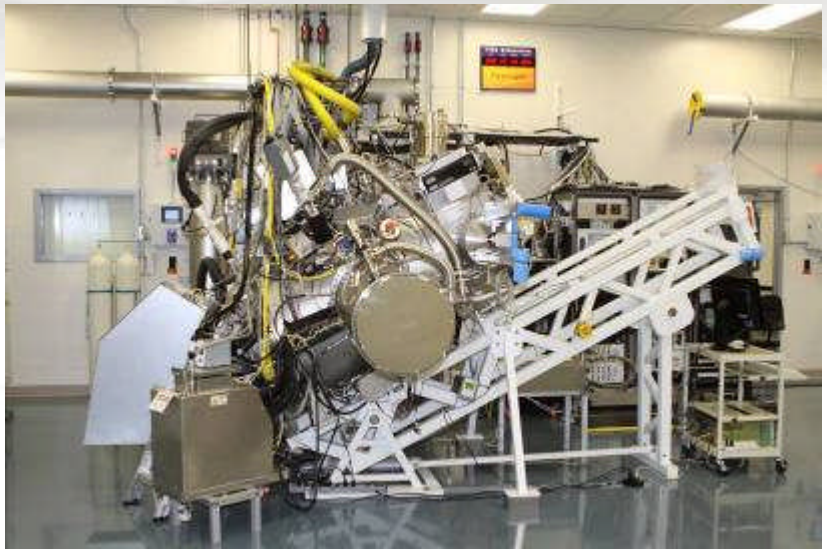
- Source vessel is delivered

HVM I source performance

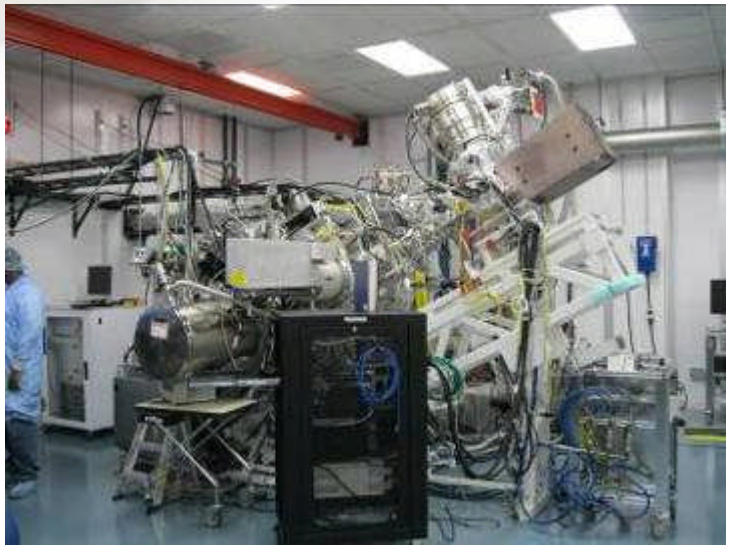
CYMER

Two Internal EUV Sources at Cymer

Upgrade Qualification and Life Testing

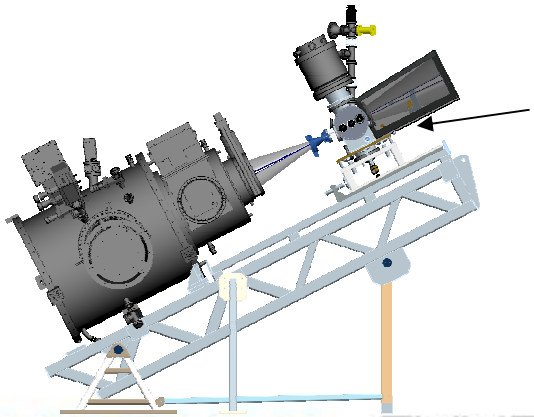


Internal source #1 (Vessel)



Internal source #2 (Vessel)

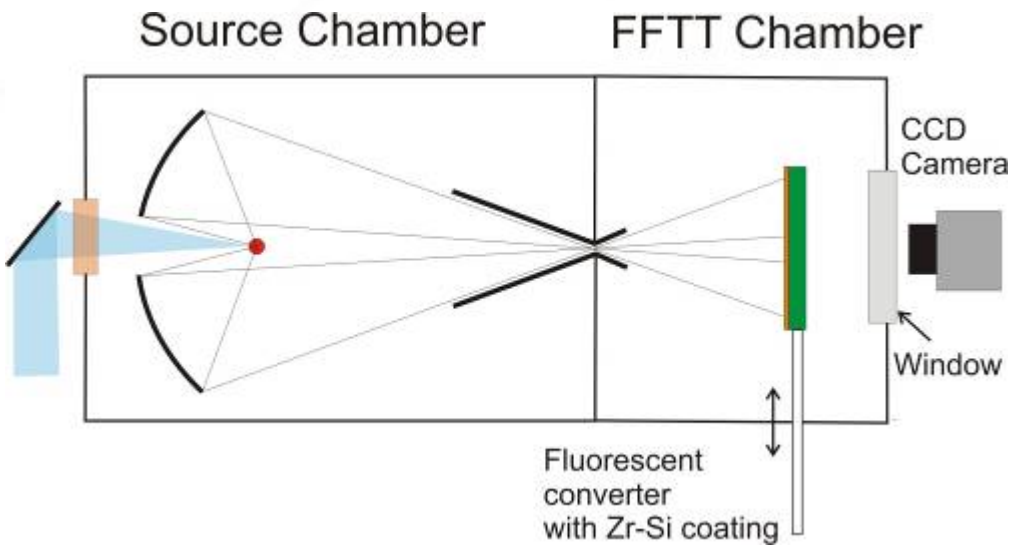
- Two internal HVM I sources are available and being used by Cymer Engineering for testing and validation of designs and upgrades
- 100 hour qualification run completed



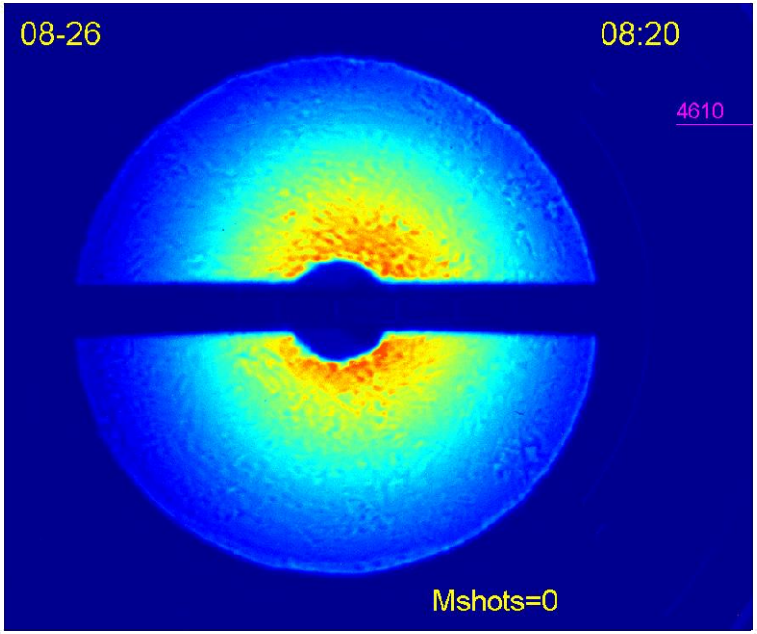
100+ hour qualification test on HVM I source

Far-field intensity pattern past IF

- Operation at 40% duty cycle and 15W exposure power
- 4.6 Billion pulses / 2.9 MJ at IF accumulated in 100 hrs over a 5 day period

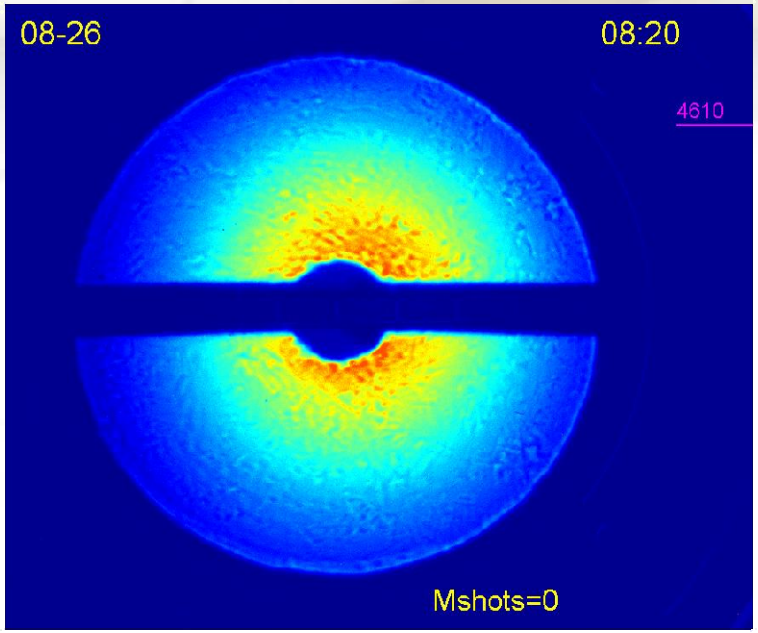


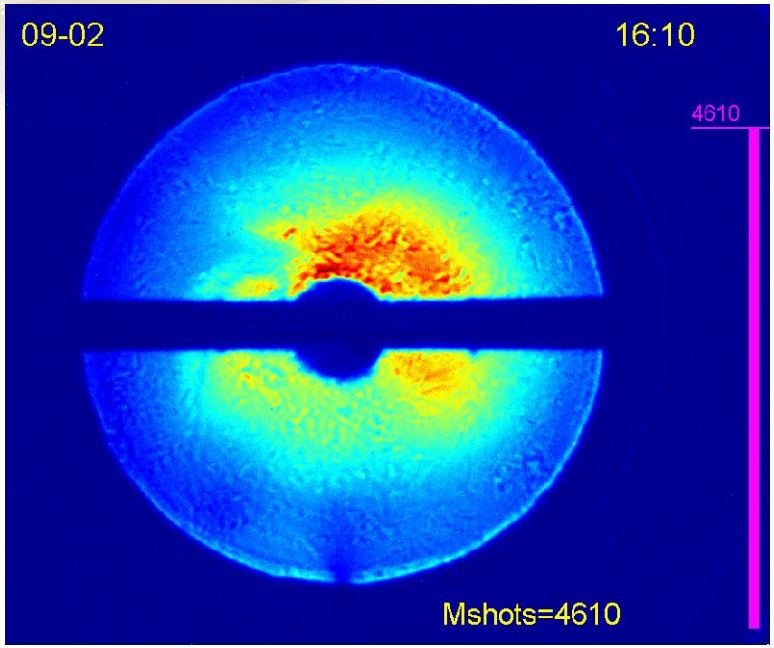
Far-Field Test Tool (FFTT)



Far-field intensity past IF

Collector Protection: 100 Hours at 40% Duty Cycle

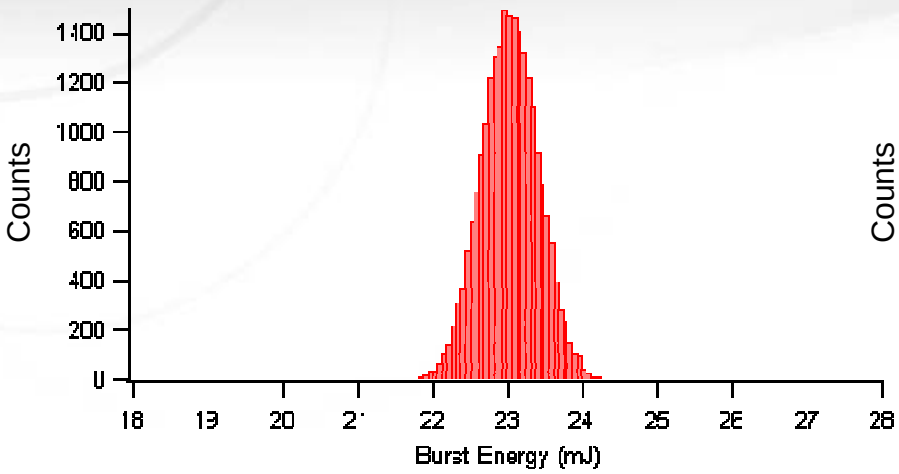




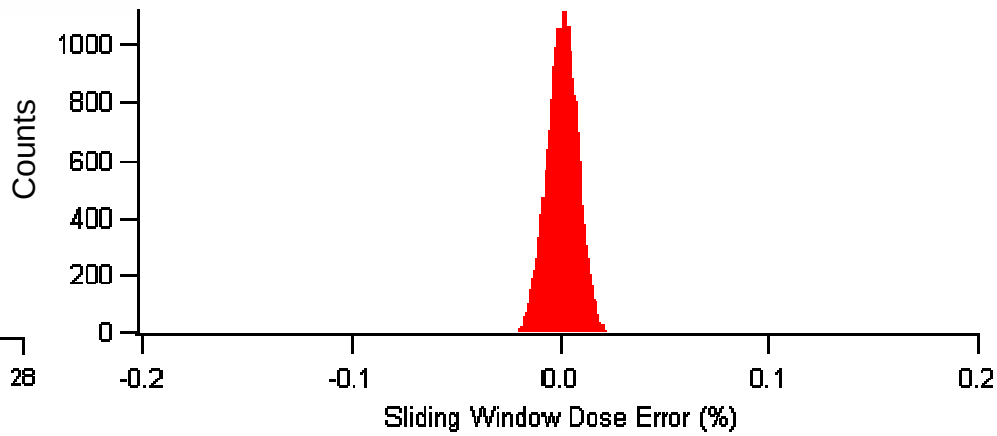
- Far field image of the collector at 0 hours
- Far field image of the collector at 100 hours

Dose control was active and set to 23W (~15W exposure)
Collector is 5sr solid angle (~650mm diameter)
Droplet diameter is 30μm

Power and Dose Stability during 100hrs / 40% Duty Cycle Qualification Test



Burst Energy



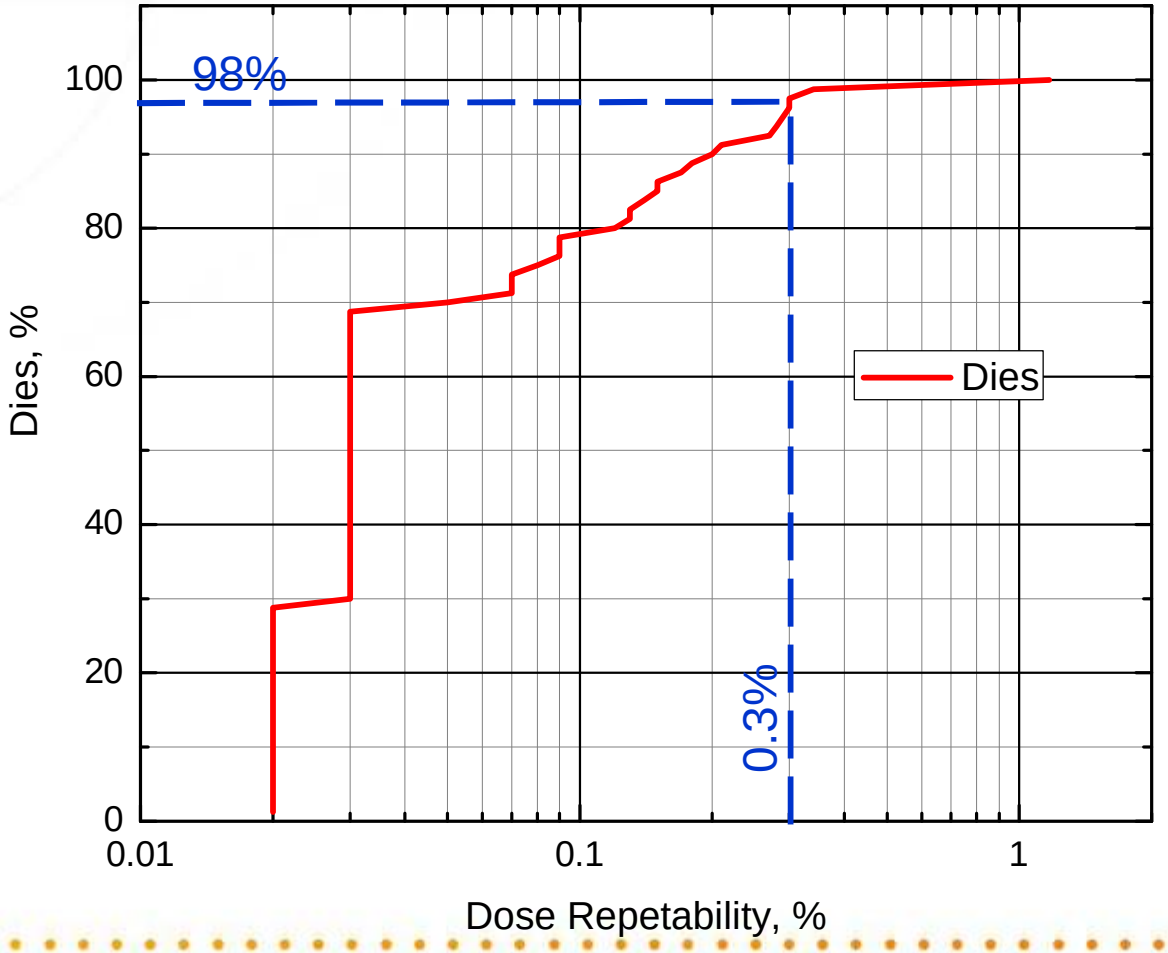
Dose Error

- Dose control operating ~15W Exposure Power assuming 65% SPF transmission
- Dose stability over entire run was ~4%, with champion performance <±0.1%

Dose Repeatability over Full Wafer

HVM I source capabilities

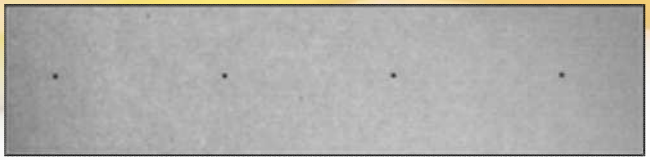
- HVM I source has demonstrated feasibility of controlling dose to within 0.3% for 98% of the dies on a wafer.



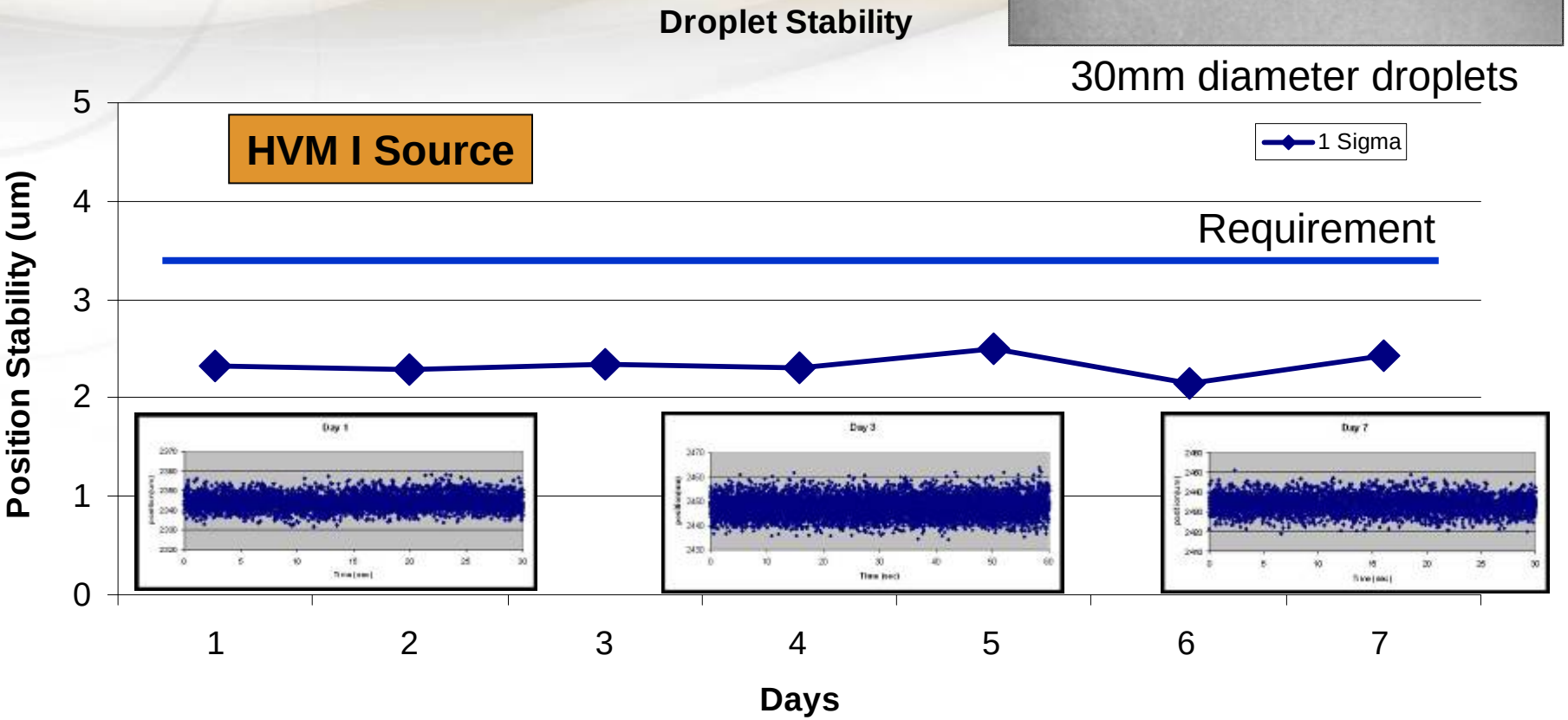
125 fields per wafer

Droplet Position Stability in Source

Daily Health Check Parameter



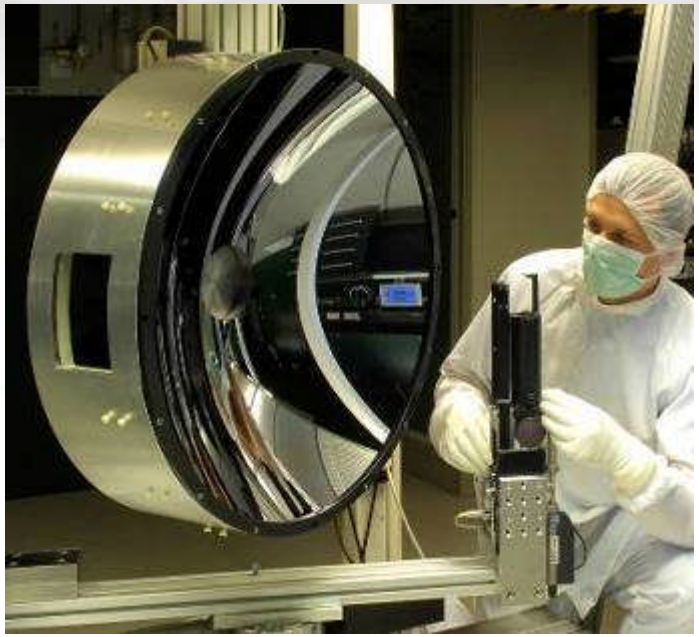
30mm diameter droplets



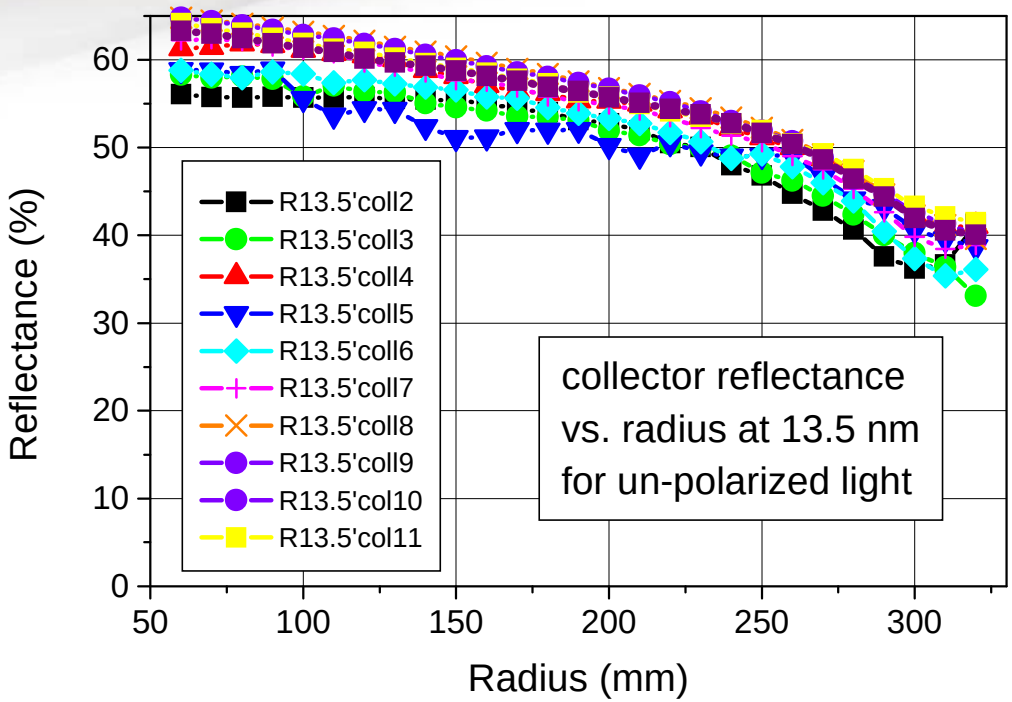
- Measured droplet position stability over 7 days
- Feedback control (active stabilization) in two dimensions
- Position stability meets requirements (<10μm 3σ)

5sr Collector Reflectivity Measurements

Average reflectivity >50%, Measurements of 10 Collectors



Mapping surface of collector



- **52.1% average area-weighted reflectivity reached at 13.5 nm**
  - Collector reflectivity measured at PTB using synchrotron radiation
  - Reflectivity for un-polarized light determined from data measured with s-polarized light

HVM I source power upgrades

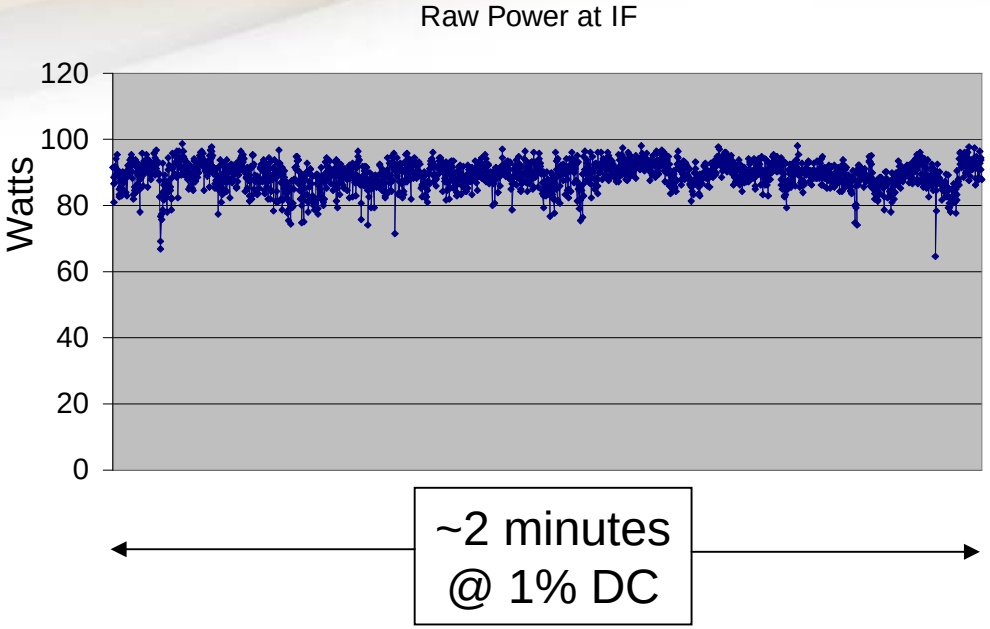
CYMER

HVM I source power upgrades

1. Drive Laser
   - Initial feasibility of drive laser upgrade (80W raw EUV on LT1, Oct.'09) now validated on HVM I source (>80 W raw EUV power)
   - Qualification of 80 W raw EUV power operation with collector
     (~ 40 W exposure power) in 4Q10, leading to field implementation in 1Q11
2. Pre-pulse
   - Successful feasibility demonstration
     - 175 W raw power achieved
       - *(consistent with ~100W Exposure Power)*
     - 3% conversion efficiency achieved
   - Next is the qualification of pre-pulse on an HVM I source platform
   - Field upgrade available mid-2011

Upgrade #1: Drive Laser Upgrade Implementation
on HVM I Source

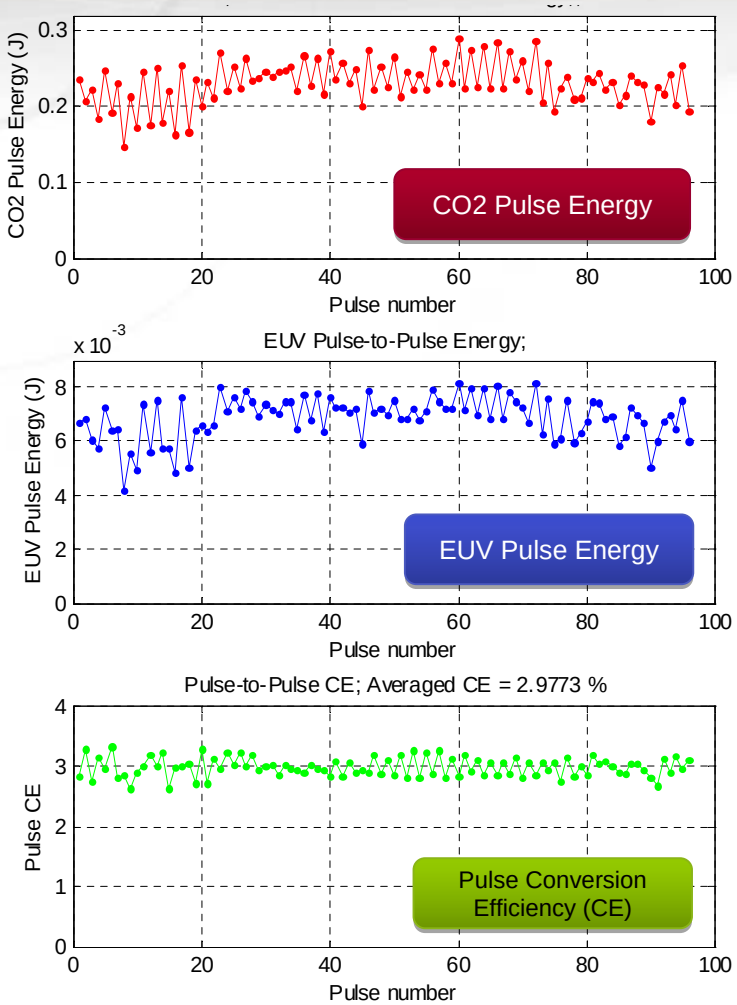
Drive Laser (with 1st Power Upgrade)



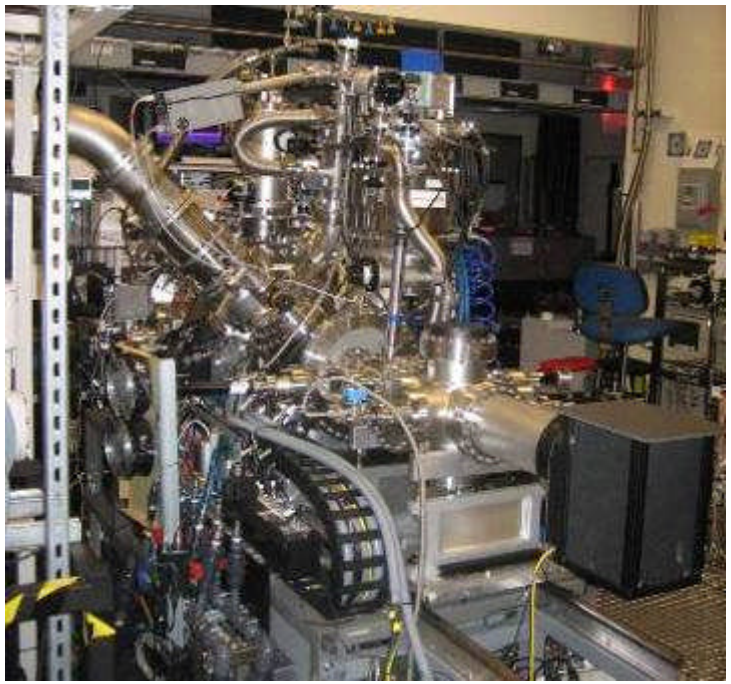
Raw EUV Power on Internal HVM I Source

- Feasibility testing on LT1 produced >80W raw power in 2009
- Qualification testing on internal HVM I source in 2010 reproduced this level of raw power (without a collector)
- Three drive laser upgrades already installed at ASML

Upgrade #2: 175W Raw Power at IF with Pre-pulse on LT1



- 3% CE confirmed
- Test duration ~1.5 hours

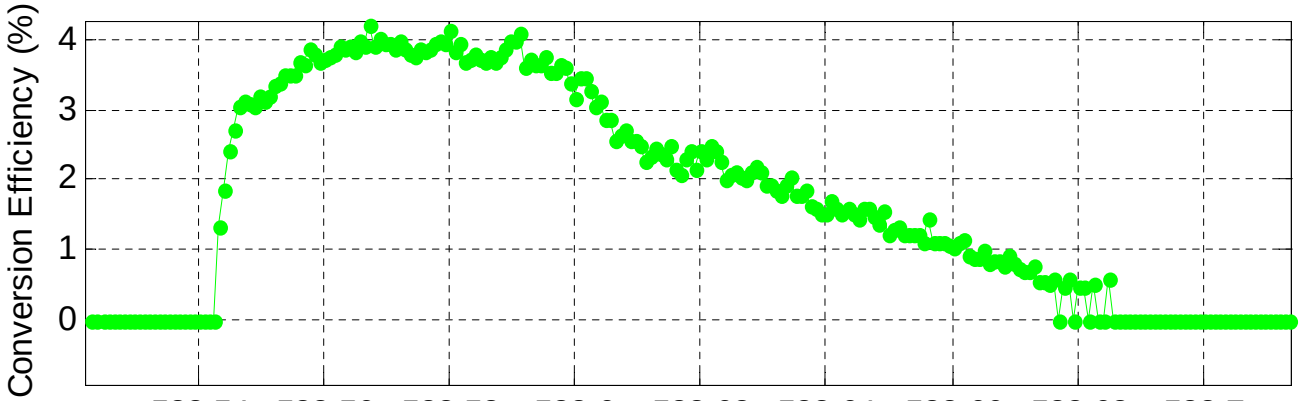


LT1 Development Source

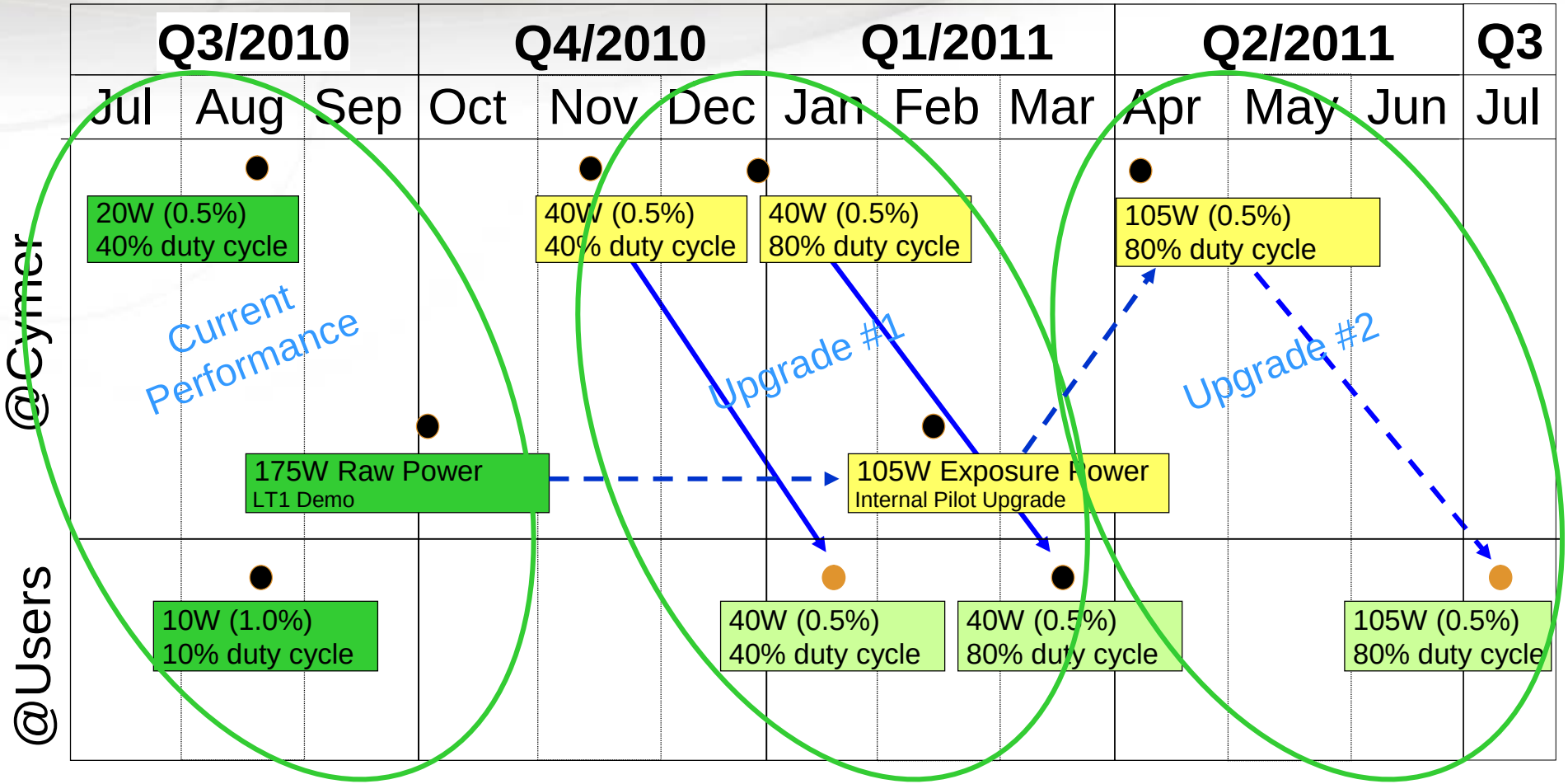
Further Power Scaling (HVM II)

- Conversion efficiency optimization with pre-pulse and laser pulse shaping
- Peak conversion efficiency ~ 4% measured using pre-pulse
  - Average conversion efficiency can be improved by eliminating the decaying tail of the laser pulse

Conversion efficiency within ~150 ns pulse



Cymer Source Power Roadmap (Oct. 2010)



HVM II Architecture

CYMER

HVM II Power Scaling

- Target exposure power > 250 W
- 2.5X scaling achieved through:
  - Laser power (>1.4X)
    - Increasing the CO_2 laser stored energy
      - *Known engineering changes to increase gain volume*
    - Improve extraction efficiency
  - Conversion efficiency (1.15X)
    - Pulse shape and pre-pulse optimization
  - Improving overall efficiency
    - Collector (1.1X)
    - Dose control (1.2X)
    - Spectral purity filter (1.15X)

Roadmap and Summary

CYMER

LPP EUV Source Roadmap

2008 2009 2010 2011 2012 2013 2014 2015 2016

EUV Source Power Roadmap			
	HVM I*	HVM II	HVM III
Drive Laser Power (kW)	**25**	**35**	**37**
In-band CE (%)	3.0	3.5	4.0
Collection Efficiency (sr)	5	5.5	5.5
Collector Reflectivity (%)	50	50	50
Clean EUV Power (W)	**>100**	**>250**	**>350**

Laser Produced Plasma R&D

HVM – EUV Light Source Generations

- Prototype

HVM I*

HVM II

HVM III

* After Upgrade

2008 2009 2010 2011 2012 2013 2014 2015 2016

Summary

- HVM I Implementation
  - Four HVM I sources shipped. The first is operational and has been used for full field / full wafer / scanning exposures
  - Source availability >70% achieved at ASML
  - 100 hour test completed on an internal HVM I source in San Diego at 15W exposure power and 40% duty cycle
  - 175 W / 3% CE feasibility with prepulse completed on LT1
  - <0.3% full wafer (98%) dose stability demonstrated

- Two power upgrades planned in January and July 2011
  - >80W raw power (40W exposure power)
  - 3% CE with pre-pulse

- HVM II source architecture development complete

Acknowledgements

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

PTB

ASML

Fraunhofer
IOF

UC San Diego

UCF

NIST
National Institute of Standards and Technology

Berkeley Lab

Please see our poster SO-P01 and papers of our development partners

CYMER

Leading the Light Generation.

CONFIDENTIAL © 2009 Cymer, Inc.